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Triboelectrostatic Process of Combustion Fly Ash after Carbon Burnout

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Abstract

Coal combustion fly ash can be considered to be a complex physical mixture of very small particles. The value of some of the components, for example – cenospheres, is greater than the value of other components. Although beneficiation techniques based on flotation, density and magnetics have been studied for years in efforts to extract fly ash components, only recently specificity has been examined for pneumatic transport, triboelectrostatic technology. Because it beneficiates on the basis of the particulate's surface electronic properties, triboelectrostatics may be expected to extract different components more efficiently than those by other techniques.

We will discuss the selectivity for beneficiation fly ash after carbon burnout as obtained by using pneumatic transport, triboelectrostatic techniques. In our previous work in this area we were able to separate products by color, particle size, density and crystallinity. The parent ashes had been collected at utilities, but the carbon burnout had been accomplished in a laboratory furnace at 750°C for 16 hours. We extend this work by beneficiating a fly ash that has been subjected to carbon burnout in a commercial facility and then by comparing these data to our previous beneficiation data for laboratory-prepared samples. Unique particulate extraction potential is shown and discussed.

Introduction

Coal combustion fly ash is a valuable component in cement where it can add strength and sulfate resistance. It is also used for structural fill and road materials, is an excellent soil stabilizer and nutrient modifier, can help to stabilize and solidify wastes, is the primary source for industrial-grade cenospheres, and is a potential source for specialty carbon [1].

An important physical property that limits the use of fly ash is its loss-on-ignition (LOI) content. Although advanced combustion technologies can achieve greater than 99.5% carbon conversion efficiency, it is still difficult to reduce the LOI content of fly ash below the value defined by ASTM C618-89a and C311-902 classification (6%) for cement admixture [2]. Additionally, the installation of low NO_x burners at power stations throughout the US has also led generally to an increase of fly ash LOI contents. Since the LOI content is equivalent to the carbon content for class F fly ash, efficiently reducing residual carbon from fly ash is of practical importance.

Because over 68% of coal combustion fly ash produced in the US is handled dry [3], it would be advantageous to apply advanced, dry technologies for the beneficiation of fly ash. Currently, two dry technologies are available, one of which is based on triboelectrostatics and other of which is based on carbon burnout. This paper reports on the use of an alternate and advanced triboelectrostatic technique on carbon burnout samples.

Triboelectrostatic separation technologies rely on establishing a dipolar charge on distinct carbon and ash particles, and then separating these dipolarly charged particles under the action of an applied electric field. Usually, carbon-deficient ash components are charged negatively, while carbon-rich components are charged positively [4-6]. Selectivity to more products is possible, and depends on the surface physical properties of the particles. Recent work in mineral separation has shown that it was possible to selectively separate inorganic fine particles by triboelectrostatics [7].

Our previous initiating work in triboelectrostatic beneficiation of carbon burnout ashes has shown [8] that value-added products could be extracted on the basis of color, particle size, density and crystallinity. The ash used in previous work was supplied by utilities but the carbon burnout was accomplished in a laboratory furnace at 750°C for 16 hours. The results presented in this paper are a continuation and expansion of this type of work. The fly ashes that have been subjected to carbon burnout in a commercial facility were beneficiated in one of our continuous feed, triboelectrostatic separation systems. The data obtained will be compared to our previous data.

Experimental

The continuous feed, bench-scale, triboelectrostatic separation system is shown in Fig. 1. In each run, about 400 g of ash sample was fed from a vibratory feeder and pneumatically transported to a separation chamber. Charged particles were beneficiated within this parallel-plate, electric field chamber using electric field strength near 500 kV/m. The beneficiated products were collected using high efficiency cyclones. During single stage tests, three products were collected and are defined as an ash product (low LOI), a carbon product (high LOI), and a recycle. In some tests, these products were then reprocessed separately in a second stage of processing. After this second stage, a total of nine products were obtained. Mass balance and closure on the LOI contents were obtained for all tests.

Three carbon burnout ashes were supplied by an industrial associate. The burning conditions for parent burnout carbon ashes were unknown. These samples were subjected to beneficiation. The parent ash and their separated products were analyzed for LOI content at 950ºC for 4 hours. Optical microscopy was performed using a Leica GZ7 microscope at magnification up to 140x; images were stored using Olympus DP10 microscope digital camera. Scanning electron microscopy (SEM) was accomplished using a Hitachi S2700. The crystallinity of the samples was analyzed by X-ray diffraction, whereas the particle density of samples was measured using He autopycnometer.

Results and Discussion

The LOI contents of the three parent carbon burnout ashes, labeled as SE1, SE2 and SE3, were measured to be 2.4%, 2.8% and 2.8%, respectively. They were subjected to triboelectrostatic beneficiation using our continuous feed, bench-scale separation system, which has a feed rate capacity between 1-50 kg/hr. Figure 2 presents the ash recovery data, plotted as a function of the relative LOI content for the SE2 sample. It shows that about 60% of feed ash would be recovered with LOI contents that were 50% less than the feed ash. If the LOI content were to be reduced only 30%, over 80% of the feed ash could be recovered.

The parent ashes (after carbon burnout) were gray-tan in color. After triboelectrostatic beneficiation, the low LOI products appeared white-yellow in color. Under microscopy observation, a great number of white, transparent cenospheres were found with a diameter between 10-70 μm. A few number of black spheres were also observed in these low LOI products, probably associated with carbon or metal incorporation in the glass phase. The high LOI products contained a large amount of black irregular-shaped particles, similar to those for residual carbon particles. The SEM pictures show in Fig. 3 and microscopy images in Fig. 4 present some of these observations.

Particulate densities of the parent ash and products of separation are presented in Fig. 5, plotted relative to their LOI contents. It shows that the particulate density increased with increasing LOI content. The density of the highest LOI product (~ 6.8 % LOI) was 11% higher than that of the lowest LOI product (~ 0.44 % LOI). This data cannot be explained by the fact that carbon density is generally lower than ash (quartz) density. However, the density difference obtained may be understood by a qualitative comparison of crystalline analysis using X-ray diffraction for the low LOI products and the high LOI products.

Figure 6 shows a comparison of X-ray diffraction spectra of the carbon burnout SE2 ash, its lowest LOI product and highest LOI product. It can be seen that the peak count of quartz (Qz) in the low LOI product is 5.8 times higher than that in the high LOI product, implying that a larger amount of quartz existed in the low LOI product than that in the high LOI product. The ratio of peak intensities of quartz to mullite (Mu)/hematite (Hm) in the low LOI product is much greater than that in the high LOI product. Moreover, the peak intensity of quartz measured in each of separated products is reversely proportional to the particulate densities of these products, as shown in Fig. 7. Realizing that the particulate densities of mullite (3.23 g/cm^3) and hematite (5.26 g/cm^3) are much higher than that of quartz (2.65 g/cm^3), a larger amount of relative lower-density quartz existed in the low LOI product may be responsible for its lower particulate density. These data clearly demonstrated that it is possible to beneficiate carbon burnout ashes on a basis of particulate size, density and crystallinity to extract high value components by triboelectrostatic beneficiation technology.

Summary

The experiments on triboelectrostatic beneficiation of coal combustion fly ash after carbon burnout demonstrated that physically distinct components could be selectively extracted from their mixtures. The selectivity of extracting high value components depends on the physical properties of components such as particulate size, density and crystallinity. Because it is simple, efficient and cost less process, the triboelectrostatic beneficiation technology may offer further opportunity for fly ash utilization.

Acknowledgements

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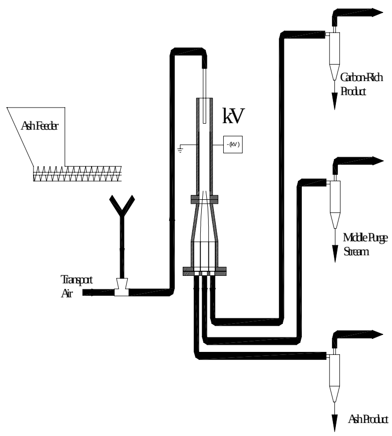


Figure 1. Schematic of triboelectric separation system.

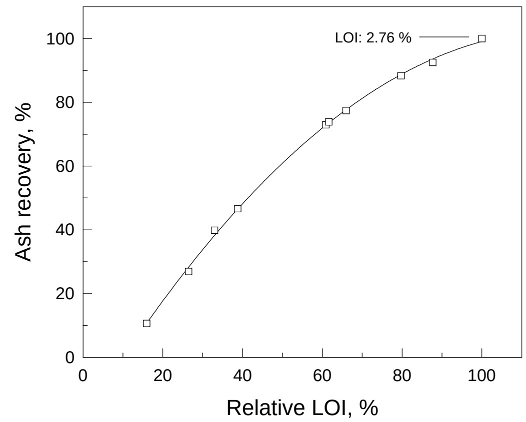
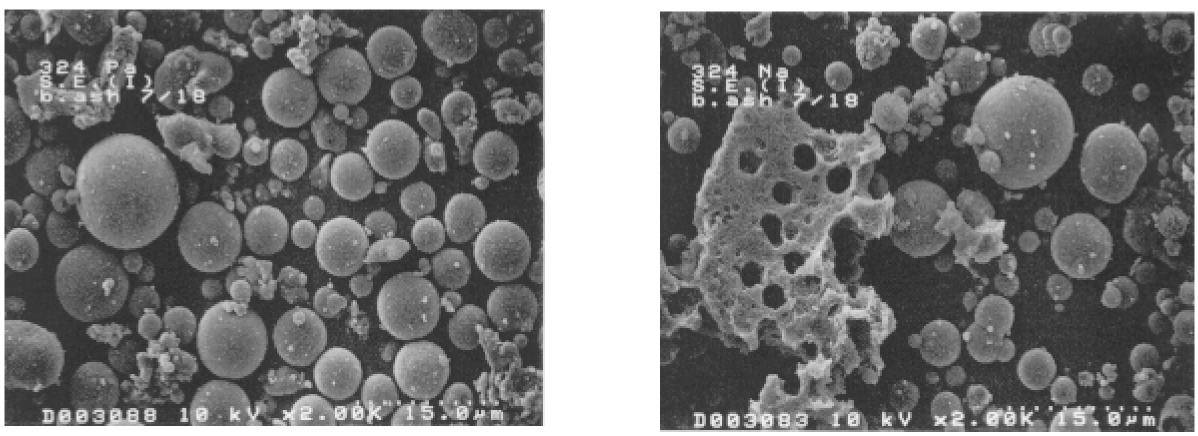
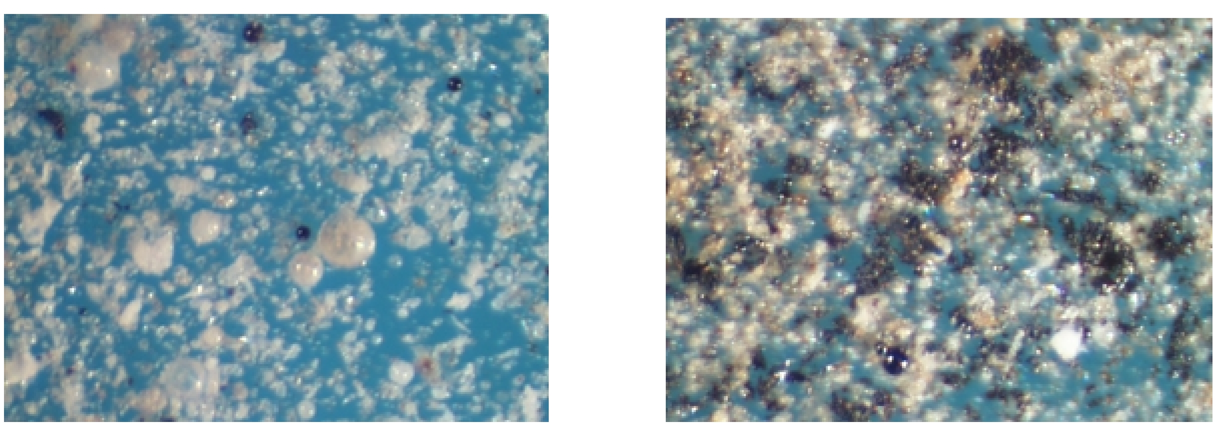


Figure 2. Ash recovery versus relative LOI content.



(a) (b)

Figure 3. SEM pictures of carbon burnout ash products: (a) low LOI product and (b) high LOI product.



(a) (b)

Figure 4. Microscopy images of carbon burnout ash products: (a) low LOI product and (b) high LOI product.

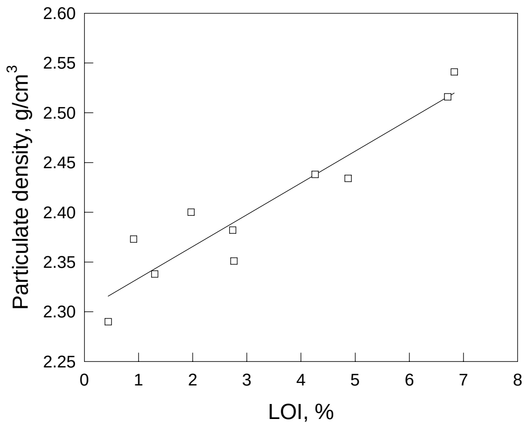


Figure 5. Particulate density versus LOI content for separated ash products.

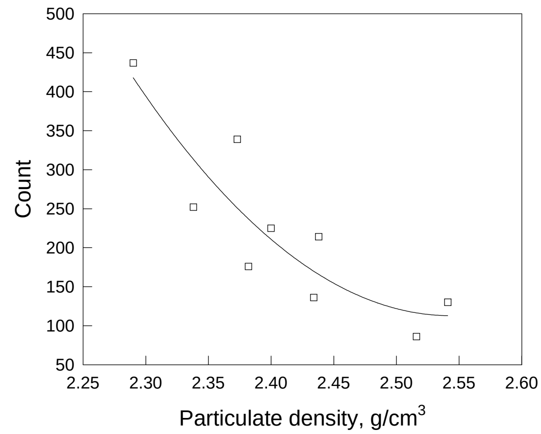


Figure 7. Peak intensity of X-ray diffraction for quartz versus particulate density for separated products.

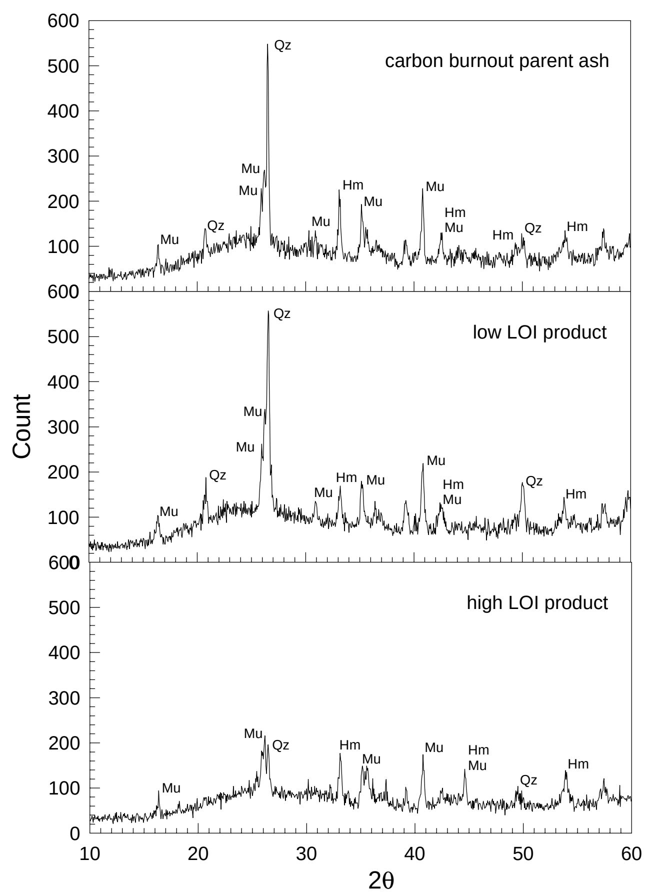


Figure 6. A comparison of X-ray diffraction spectra of carbon burnout parent ash, its low LOI product and high LOI product. Qz: quartz, Mu: mullite, Hm: hematite.